PAPERS ON THE REALITY OF METEROLOGICAL PERIODICITIES

I. INTRODUCTORY NOTE

By C. F. MARVIN

It is interesting to present in the accompanying articles the opposing views of two prominent hydrologic engineers concerning periodicities in rainfall and stream flow.

The perplexing question of the underlying laws controlling meteorological sequences can not be disposed of by simple theories. Deductions must follow observational data and be consistent with known physical laws.

Constancy in consecutive values of meteorological data is an unknown characteristic, whether we examine individual values of such groups as monthly, seasonal, annual, or lustrum means, etc. The same is true with data treated by smoothing formulæ. Ceaseless fluctuations in consecutive values is the outstanding feature of the time function of meteorological data. We can not, in advance of suitable summaries of actual observations, safely proceed on the theory that more or less striking fluctuations will not be found in data, even for the entire globe, if appropriate units and summaries are employed.

Every investigation of meteorological sequences encounters at the outset the question: Is the order of succession of values fortuitous and lawless, or is it systematic and controlled, in some slight degree at least?

Mr. Clough[1] has summarized the greater part of what is known of the mathematical characteristics of purely fortuitous data as compared with those displayed by meteorological statistics. The latter, when tested by one or more criteria, rarely fail to show that the order of succession of the natural data differs more or less from a perfectly fortuitous one. This would doubtless prove to be the case with most of the sequences shown by Mr. Streiff, as well as those of Mr. Grunsky. Such being the case, the data call for appropriate interpretation. However, statistical evidence that the order of succession in California rainfall is controlled does not imply that Mr. Streiff's paricular interpretation is necessarily confirmed. If we say the features are periodic, the word period must be very liberally defined to signify recurrences at intervals which may differ in length at least 100% in extreme cases and with variations in amplitude also. No better appellation than "periodicity" has yet been proposed for these irregular recurrences, and a good deal of skepticism about meteorological periodicities is aroused when the sense in which this word is necessarily used is narrowly construed.

The recurrent features develop with greater or less regularity in all classes of data and undoubtedly call for segregation, study, and interpretation.

The Brückner period (25 to 35 years) is so long and so obscure that observations for 150 to 200 years are absolutely necessary to even fairly demonstrate its reality. Nevertheless, evidence of its presence in shorter records can not be entirely disregarded.

A partial harmonic analysis of the California rainfall percentages from 1851 to 1926 gives for the San Francisco and Sacramento values a large, well-defined secular trend, characterized by moderate values after 1850, rising to sustained maximum ratios during the eighties, followed by low minimum values about 1916 and tending to higher values at the present time. This secular trend is quite accurately represented by a 70 or 80 year period, but it would be folly to claim that such a period is real; it is simply a secular trend. The amplitude of any short period around 30 to 35 years is quite insignificant in the central California data, but a period of 20 to 26 years has a relatively larger amplitude of about 15 per cent above or below normal.

The San Diego values are in close accord with those of central California up to 1907, but remained generally above normal thereafter. The secular trend is, therefore, missing. The amplitude of a 36-year period comes out below 15% with crests at 1881 and 1917, whereas the 24-year period has about the same amplitude, the two periods in this short record being mathematically independent.

These results indicate how different and uncertain conclusions are when they are drawn from records of inadequate length.

[1] MONTHLY WEATHER REVIEW, March, 1921, 49: 124–132.

II. THE IMPROBABILITY OF RAINFALL CYCLES

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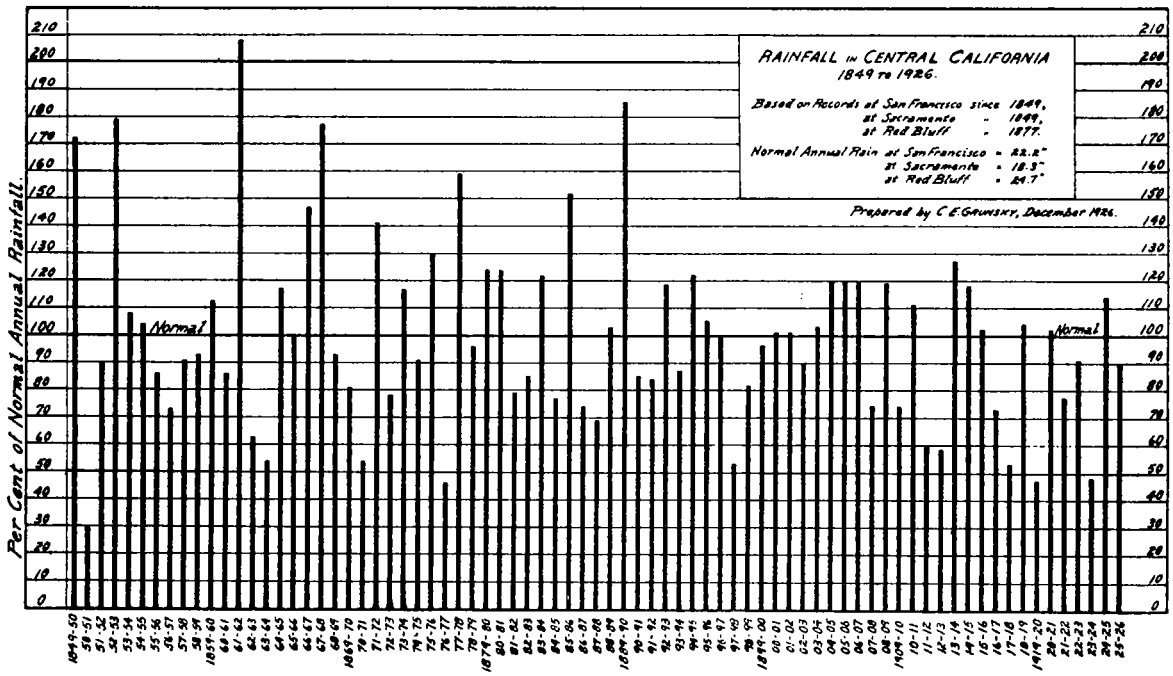
[San Francisco, Calif.]

There has just come to the writer's attention the article by Mr. A. Streiff "On the investigation of cycles and the relation of the Brückner and the solar cycle," published in the MONTHLY WEATHER REVIEW of July, 1926. His conclusions are by no means convincing. The fact is so well known that the annual precipitation on the surface of the earth, taken in its full extent, may be accepted as equal to annual evaporation—if transpiration be included in evaporation in the sense as here used—and that the amount of heat which reaches the earth from the sun year by year varies within such narrow limits, that aggregate annual evaporation, and consequently precipitation, on the entire surface of land and water, when one year is compared with another, may be accepted as constant in amount. There must, therefore, be a more or less complementary relation between those regions in which there is a deficiency of rain in any year (compared with normal) and those other regions in which there is an excess. Moreover, the complementary regions are not persistent in location or area. There is never-ending change, much more likely to be caused by slight variation in ocean currents and ocean temperatures than by activity in the solar chromosphere. Rainfall for this reason is not at all likely to respond to or to harmonize with cycles of solar or planetary influence. This is partially true also of tree rings when they are used as indices to climatic conditions. The growth of the tree is only occasionally, as in parts of California and only when suitably located, an index to droughts and to wet years.

An illustration or two may suffice to show how little dependence can be placed on rainfall and stream-flow records for the deducing of cycles and to show that careless use thereof must always throw doubt upon resultant conclusions. In noting average rainfall conditions throughout California the United States Weather Bureau

quite properly makes use of 12 records widely scattered. The rainfall at Red Bluff and at other stations is grouped with the rainfall at San Diego to obtain averages, even though it is well known that, particularly in the winters of the dry type in this State, when our main LOWS enter from the ocean far to the north of Oregon and produce only light rain in northern and central California, there may be heavy rainfall at San Diego resulting from entirely unrelated southern storm conditions. As examples of the lack of consistent correlation, the following comparison of the rainfall in terms of the annual normal in the vicinity of Los Angeles with that in central portions of California, all of which show wide departure from the ordinary relation, may be cited. This comparison is based on the rainfall records at three stations, Los Angeles, San Bernardino, and Santa Barbara for rain in the vicinity of Los Angeles and on San Francisco, Sacramento, and Red Bluff for rain in central California.



Season	Percentage of normal in—		Season	Percentage of normal in—	
	Central California	Near Los Angeles		Central California	Near Los Angeles
1850-51	30	86	1895-96	105	60
1859-60	68	113	1903-4	103	60
1864-65	117	87	1915-16	102	143
1871-72	141	69	1917-18	53	98
1880-81	124	85	1919-20	47	95
1883-84	122	226	1921-22	77	133
1887-88	69	107			

Mr. Streiff, in the article above referred to, in discussing cycles combines the San Diego record with station records as far north as The Dalles and Astoria, thereby invalidating in some measure the sequence of wet, of normal, and of dry years, which the northerly records considered alone would indicate.

On a diagram (fig. 1) herewith submitted there is shown the rainfall in central California based on the three dependable records, San Francisco, Sacramento, and Red Bluff, a mere inspection of which will show the hopelessness of using Pacific slope rainfall records as a basis for the determination of cycles from records even as long as 80 years.

The rainfall is expressed in this diagram in percentage of normal. The figures given as the averages can be applied with confidence to any portion of central California for which the normal rainfall is known. The percentage of normal for the individual years at the three selected stations are in such remarkably close agreement that the composite values shown in the diagram may be accepted as a better indication of rain conditions which have produced run-off than any single station record. It will be noted that in central California from 1849 to 1890 there were quite a few rain years (July 1 to the following June 30) in which precipitation exceeded normal by 50 to 100 per cent. There have been no such years since 1889–1890; and yet they must be looked forward to with certainty as to their occurrence at some time in the future. No one can foretell when the next very wet climatic year or group of wet years will occur. There is no possibility of any forecast thereof by the use of sun-spot or any other cycles.

That the varying radioactivity of the sun and its periodic extreme conditions as manifested by minimum and maximum sun-spot frequency is very likely to influence plant life, and therefore to have an effect on the growth of trees, appears clear, but conclusions as to rainfall should not, as already intimated, be drawn with too much confidence from the appearance of tree rings.

The use of stream flow in a study of meteorological cycles introduces new factors of uncertainty. The stream flow is not definitely related to the rainfall. It is well known that in the West, for example, the distribution of the rain to the several months of the year, or, better, its amount during individual rain storms and the sequence of the several storms of the year, influences greatly the amount of run-off. Any established relation between between rain and run-off is only a probability, from which wide departure must be expected. A new source of error

is therefore introduced when stream flow is used in the study of weather cycles. Furthermore, for only very few streams are dependable records available for long-time periods. Then, again, in such cases as the flow of Niagara River and the elevation of Lake Ontario there are other disturbing factors. Evaporation from the Great Lakes has a relatively wide range and directly modifies the outflow of water from the lakes, disturbing the correlation of rainfall and water production. Below Lake Ontario is the Cut Dam across one of the branches of the St. Lawrence. The lake elevation fluctuates within narrow limits; the dam affects the lake stage more or less. There should at least be a separation of this lake record into two portions, one before the construction of the dam and the other subsequent to its construction. Other human activities have affected the stages of the Great Lakes and the outflow from them, all of which should be taken into account in determining stream flow or water production when such data are to be used in the manner of Mr. Streiff's paper.

It is quite probable that all efforts thus far made to find long-term cycles in the varying annual precipitation or in the stream flow are premature, even as it may be considered certain that variations in rain corresponding to one-third and other fractions of the solar cycle—as suggested by some students of meteorology—are mere accidents and can never be conclusively established.

In further explanation of the futility of correlating precipitation and sun-spot frequency and as basic data for students of the subject, a second diagram has been prepared showing four curves as follows: The progressive five-year average amounts of rain in terms of normal annual at the Great Lakes; the progressive five-year average water production of the Great Lakes, also expressed in percentage of normal; the stages of the Great Salt Lake, Utah; and the progressive five-year average amount of precipitation in central California.

The determination of precipitation at the Great Lakes as shown in this diagram applies to the entire watershed or drainage basin tributary to the Niagara River. It is probably the most dependable determination ever attempted for this region, being based on the records in a 53-year period, 1871 to 1923, at 47 stations in the United States and 7 in Canada, all suitably weighted to determine the normals for the 53-year period, which were thereupon used in calculating the annual percentages of normal. This compilation was made several years ago by the writer for the Sanitary District of Chicago in connection with a study of rainfall and of water production in the Great Lakes Basin.

The shapes of the curves on this diagram indicate at once that longer time is needed to prove the existence of any notable cycle, or, perhaps, to establish conclusively, as the writer believes, that none will ever be found.